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Quarterly Progress Report No. 2

**N67-80507**

DEVELOPMENT OF LASER BEAM SCATTERING TECHNIQUES  
FOR GAS DENSITY MEASUREMENT IN ROCKET BASE FLOW FIELDS

Contract No. NSR 33-009-048  
Project No. PR 10-9347

Reporting Period: 15 September 1966 to 15 December 1966

Objective

The objective of this program is the development and evaluation of a laser density probe as a diagnostic tool for measuring gas number density in simulated, short-duration, base region flows of a scale model clustered rocket configuration.

Technical Discussion

1. General

Principles of operation of the laser beam gas density measuring technique as well as the general configuration of the instrumentation to be implemented in the application of this method were discussed in the initial quarterly report. During the interim report period the details of the instrumentation design and configuration have been resolved and the program design effort has virtually been completed. The design effort, in fact, has represented the dominant project activity during this quarter resulting in the preparation of over twenty-five major drawings. These drawings have been released to NASA/MSFC for fabrication and present information indicates that the fabricated components may be expected at CAL during the latter part of January or the early part of February. Certain critical components that will be required to facilitate preliminary check tests of the laser apparatus well in advance of the actual test program will be fabricated at CAL to reduce the otherwise long lead time in fabrication. These components are all those

shown as external to the vacuum chamber\* in Fig. 1 which is a schematic of the laser source installation.

Contract modifications required to permit NASA/MSFC to supply certain laser/radiometer equipment to CAL as GFE were completed. This equipment, including the laser source, laser power supply, photo-multipliers, and interference filters has been received at CAL.

Receipt of special (EMI type 9558C) high gain, low dark current photomultipliers<sup>(1)</sup> has not yet been accomplished. Because of this delay, the radiometer design has been firmed to accept the DuMont 6911 photomultiplier which was used on an earlier CAL program<sup>(2)</sup>. Radiometer mechanical design is such that the EMI tube can be accommodated for some future program if subsequent evaluation tests demonstrate a marked superiority over the 6911.

## 2. Model Instrumentation

The semicircular base plate of the model includes a window extending the length of the 6-inch radius of the base to allow probing in the lateral dimension. A second window, located in the reflection plane, permits probing the flow field at positions up to 14 inches in the axial dimension as measured from the base plate. Figure 2 illustrates schematically the flow field plane in which density measurements may be made with this particular geometry.

Plume calculations indicate that impingement occurs at about the 5-inch position (measured from the base along the reflection plane) for the design value of the nozzle pressure ratio and at about 9 inches for about one-tenth the design ratio. Thus, the probing capability available will facilitate the examination of the impingement/base flow details for a wide range of model operating conditions.

A tray incorporating four pressure transducers has been designed to fit in either the base plate or the reflection plane window slots to allow surface pressure measurements to be made simultaneously with

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\*Except for the compensating radiometer.

laser density measurements. In addition to these four transducers, supporting instrumentation will include:

- a. expansion tube static pressure (to be used in determining the strength of the nonsteady expansion associated with initiation of flow and hence the post-wave total temperature required for calculating primary reservoir density).
- b. primary reservoir pressure (to be used to compute reservoir density using ideal gas theory).
- c. primary nozzle and calibration nozzle exit plane pressure (for monitoring nozzle performance and total test time).

System operating parameters, such as expansion tube loading pressure, temperature, and altitude chamber pressure and temperature, will be measured with conventional type instrumentation.

### 3. Cleanliness Precautions

The crucial aspect of the entire experimental program will be the cleanliness of the flow, that is, the degree to which the flow is free from particulate and aerosol type contaminants. Several precautionary measures will be instituted to minimize the contamination of the flow. First, the pressure diaphragms that are normally installed in the expansion tube and the nozzles (and then ruptured to initiate the test event) have been eliminated. A rapid acting autovalve will be used instead to preclude possible debris problems with diaphragm particles. Second, two high-retention Millipore<sup>\*</sup> line filters for use with gases have been purchased. One of these units will be installed in the expansion tube loading line. For spherically-shaped particles, the absolute retention capability of this filter is for particles of 0.22-micron diameter and larger. The other filter is a high

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\* Trade name.

flow rate cartridge style unit and will be employed to process the air re-admitted into the altitude chamber between test firings. Retention capability of this filter is for particles with a diameter of one micron and larger. Flowrate specifications for both filters are such that loading times for both vessels (the expansion tube and the altitude chamber) will be acceptably small. A number of load-unload cycles will probably be necessary prior to initiating the test program to purge the system.

The altitude chamber, fabricated from cold-rolled steel, will be sandblasted internally and immediately painted with a flat black paint\* specially developed for use in vacuum vessels.

#### 4. Calibration of Laser Density Probe

Two different approaches to calibrating the laser density apparatus will be employed. One method involves a static type test wherein the altitude chamber pressure is varied over the desired range and radio-meter electrical output is defined in terms of gas number density computed from measured gas pressure and temperature. Several potential problems are associated with this method: (a) because of the large size of the chamber (13 ft. diameter) and the fact that personnel will need to enter it to make model configuration changes and adjustments, the ability to keep the chamber adequately free of contaminants is not known, and (b) the calibration data and the test data on the model will have been taken with gases that could be of different purity.

An alternative method of calibration employing a special nozzle for this purpose is being included as part of the instrumentation system. NASA/MSFC has been requested for a method-of-characteristics design of a small, low area ratio ( $\leq 20$  on the basis of flow condensation considerations) nozzle for this purpose. Design details are expected to be received in early January.

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\* Process Equipment Co., Inc., Brockton, Massachusetts.

This nozzle will be attached to the primary nozzle reservoir and will use approximately one-tenth of the primary gas flow. Figure 3 is a schematic showing the installation of the calibration nozzle. The laser beam transits the nozzle exit plane and the scattered energy, whose magnitude is proportional to the density, is sensed by a radiometer (not shown). Other radiometers may then be calibrated relative to this unit as the standard. Density levels at the nozzle exit plane are accurately known as a function of reservoir density. The attractiveness of this method lies in the fact that the calibration is performed using the same (or the same quality gas) as that used for model tests.

Both methods of calibration will be used initially. If the data correlate satisfactorily, use of the nozzle method will probably be discontinued since the altitude chamber method affords a larger range of densities and ease of operation. Should the results disagree, the nozzle technique, which uses the model working gas as the test medium, will be used as the calibration standard.

#### Future Plans

During the next quarter, all fabrication effort will be concluded and assembly of the component parts completed. Check tests of the laser source will be made and the altitude chamber conditioned for testing. Installation of the apparatus in the altitude chamber will begin.

[REDACTED]

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#### References

1. "Development of Laser Beam Scattering Techniques for Gas Density Measurement in Rocket Base Flow Fields," Quarterly Progress Report No. 1, 15 September 1966.
2. Newton, J. F.: "Report on the Development of a Laser Density Probe," CAL Report No. 135, April 1964.

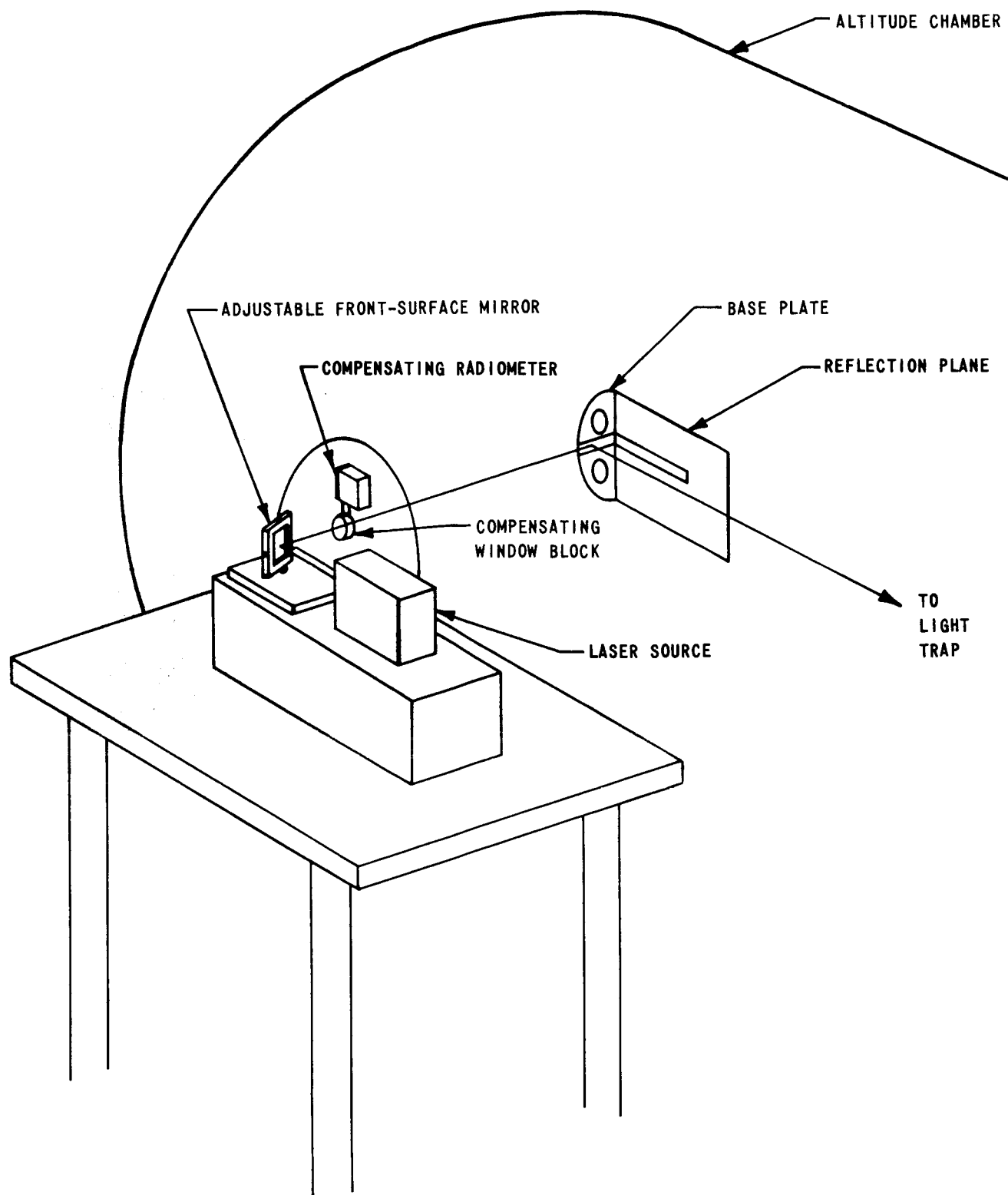


Figure 1 LASER SOURCE INSTALLATION

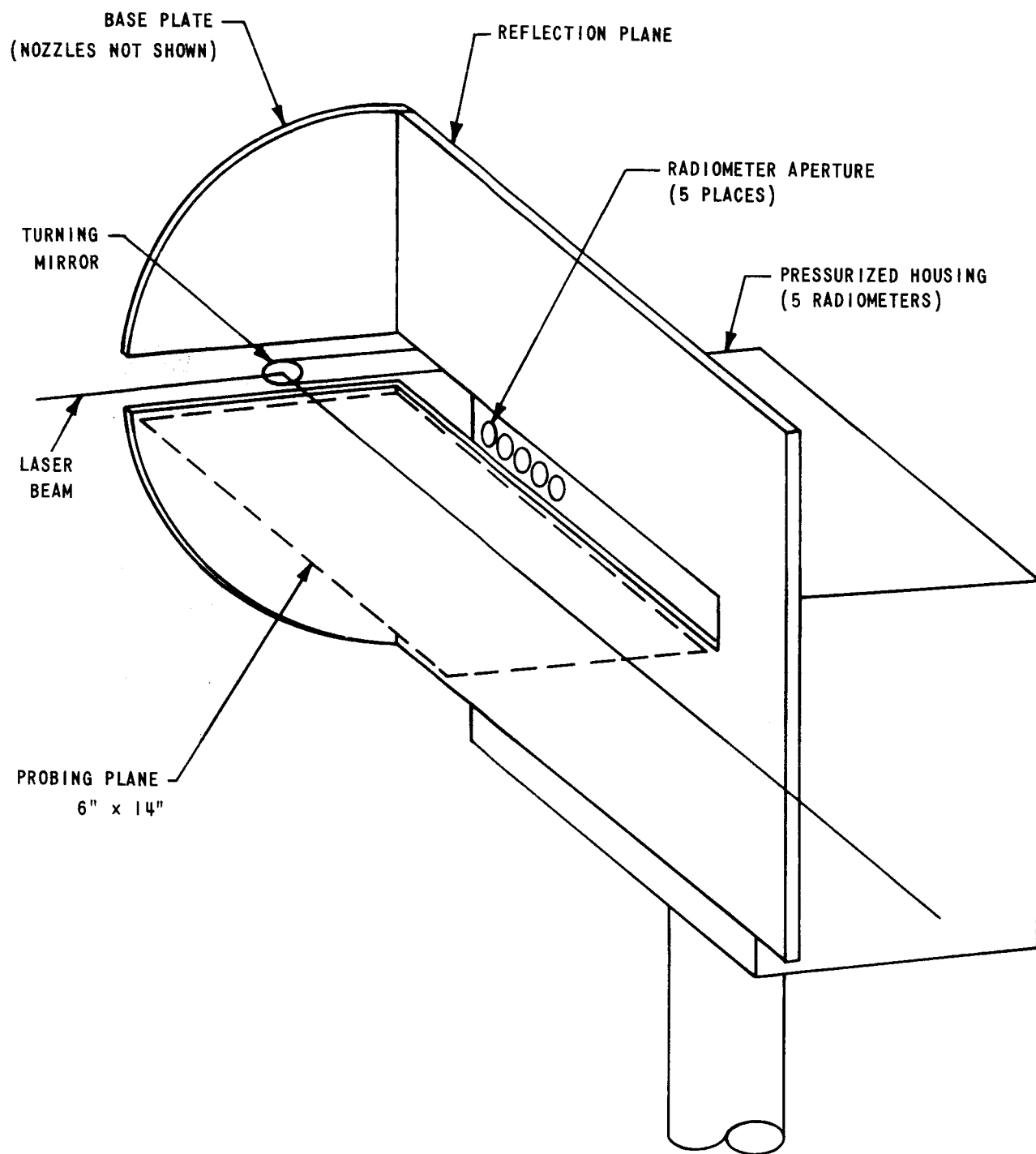


Figure 2 PROBING PLANE

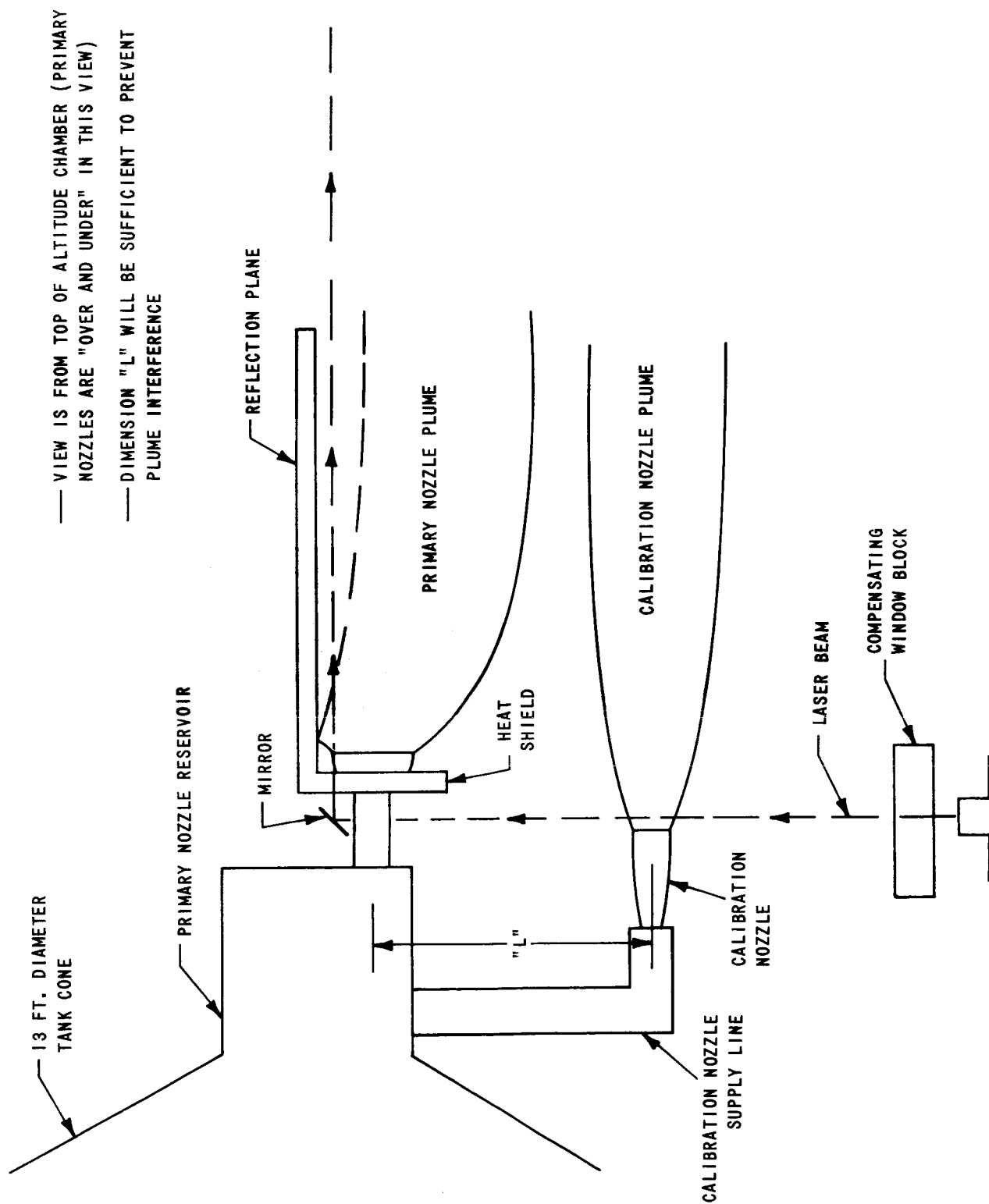


Figure 3 CALIBRATION NOZZLE INSTALLATION SCHEMATIC